POPLAR GROWING AND FARM ADJUSTMENT ON THE NORTH COAST OF NEW SOUTH WALES

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The poplar species, *Populus deltoides* provides types which are ecologically well suited to the rich alluvial soils of the north coast. This study uses a simple simulation model and linear programming to explore the economics of introducing poplars into farm plans on this soil type. If the price of poplar timber does not fall by more than 60 per cent relative to other agricultural prices, and if plantations can be financed at discount rates less than 10 per cent, then poplar growing has considerable scope for integration with other farm activities. Poplars should be included under all the farm conditions tested, namely farm sizes between 100 and 150 acres, labour forces between one and three men per farm and a doubling of dairy profitability over the present level.

1 INTRODUCTION

In terms of its rural economy the north coast of New South Wales is currently regarded as a problem area.[1] The dairy industry is the main source of employment but in this area it is characterized by low farm incomes. Agricultural alternatives for adjustment on the far north coast were examined by Bird [3]. The object of this paper is to examine the potential of poplars as an alternative for farms on the north coast.

Of the varied land types in the area only the first class alluvial flats [2] are at all suitable for poplars. Land with a clay pan or any tendency to salinity will not give optimal growth of *Populus deltoides*, which provides the best types for the area.[2] This is the species planted by Federal Match Forests Pty. Ltd. at Grafton. At a conservative estimate there are some 27,000 acres of prime poplar land in the flats of the Macleay, Richmond, Clarence and Tweed rivers (appendix I).

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[1] The term "north coast" refers to the north coast statistical division. It covers the area from the Queensland border south to the MacLeay Valley and includes the major river systems of the MacLeay, Clarence, Richmond, and Tweed.

[3] Full details of suitable sites are provided by R. M. Black [4].

There is no intensive economic analysis of the Australian demand and supply position for timber which could serve as a basis for market projection. Despite this, all forest services in Australia as well as the Food and Agriculture Organisation predict an increasing world scarcity of forest products[3]. Jacobs [7] estimates that Australian timber production will satisfy only 74 per cent of consumption in 1990, 82 per cent in 2000 and 79 per cent in 2010. There is, therefore, a background of general scarcity against which to consider future poplar markets. Poplars are are well suited to veneers and plywoods. There was a market for this product in 1969–70, and a large volume of veneers and plywood are imported. The poplar activity which is the basis of the investigation is production for this market. The effect of two other activities, which include production for particle board, have been considered in a less rigorous manner elsewhere [9].

2 THE PROFITABILITY OF POPLAR GROWING

2.1 THE ANALYTICAL FRAMEWORK

This analysis was framed to answer three questions. What is the profitability of poplars with expected yields, costs and current prices? Second, how sensitive is profit to changes in prices and yields? Costs were considered sufficiently reliable to exclude from this sensitivity test. Also the nature of the discount process means that the early costs are relatively more important, and these can readily be estimated. Third, under what assumptions of prices, yields and costs is poplar growing as profitable as currently typical dairying and efficient dairying?

A simulation model of a poplar plantation was developed to answer these questions. It was assumed that poplars were grown on an 18-year rotation and one acre was planted each year: at and after age 18 one acre was felled each year. An 18-acre unit was therefore assumed. Rather than estimate an optimal financial rotation, the single conservative age of 18 was adopted.

Two criteria of profit were used, namely the internal rate of return (I.R.R.) and the annuity at a 6 per cent discount rate. An annuity is the net income less returns to capital and management. In forestry terminology it is the annual equivalent of the land expectation value after deduction of the opportunity cost of the capital invested. Annuities are therefore the annual equivalent of a non-annual cash flow, and are calculated with the appropriate discount procedure. Both criteria were calculated with real costs and cash costs. Real costs were defined as the variable costs and fixed costs comprising a managers salary of $2,000 per year, depreciation

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[3] For example, Food and Agriculture Organization *Wood: World Trends and Prospects*, 1967.

on machinery with a 20-year life for the forestry equipment, and the opportunity costs of all other assets involved. In the annuity the opportunity cost was taken at 6 per cent: in the internal rate of return it was, implicitly, taken at the solution rate of interest (the I.R.R. itself). Cash costs excluded labour and the opportunity cost of capital.

The level of dairy income to which the profitability of poplars was compared was selected from the survey by Schaefer [8]. Schaefer surveyed 21 farms on the fertile alluvial soils of the Clarence floodplains; these soils would provide optimal conditions for poplars. The range of profits was from —\$30 to + \$45 per acre, with an average of + \$4 (table 1). When the 21 values were ranked it was noted that 85 per cent of them were less than \$16 per acre. Since these data were derived from the land type in question, the comparative levels of dairy profit were taken as + \$4 per acre on average, and an upper level of \$16 to cover 85 per cent of the farms. In this way poplars were compared to both average and high income farmers. The inclusion of a high income level allows, to some extent, for managerial factors.

TABLE 1

Profits of 21 *Farms on the Clarence Floodplain*

\$ *per acre per whole farm for* 1967–68*

Main farm activity	Average profit	Range		Number of farms
		Maximum	Minimum	
Dairy—				
Milk	3·2	19·4	—20·2	4
Cream	7·4	45·4	—29·6	4
Milk/cream	6·6	11·7	— 3·0	2
Average†	5·7	45·4	—29·6	10
Beef—				
Average†	2·3	29·7	— 6·3	11
Overall—				
Average†	3·8	45·4	—29·6	21

* Including real costs, that is, a 6 per cent charge on capital invested in land, stock and improvements, and a managerial salary, and depreciation on machinery.

† The "average range" is the extreme values.

Source: Schaefer [8].

2.2 THE DATA

A base price of \$0.67 per cubic foot was adopted and is the lowest price that a grower on the Clarence would obtain for poplar raw material in 1969—thinnings were assumed to be unsaleable. A "cautious" price structure of \$0.55 per cubic foot, with thinnings assumed to be unsaleable, was also used together with a "development" price structure, which assumed local markets for all timber had "developed". This "development" price structure was assumed as follows. If a plywood manufacturer were to establish in Grafton and if thinnings were to be saleable to a pulp mill or board manufacturer within 50 miles, it is expected on 1969 prices that $0.55 per cubic foot would be obtained for plywood raw material and $0.05 per cubic foot for the thinnings and for 10 per cent of the final crop. The sensitivity of the profits to this range of prices was tested.

Cost and yield data, together with some technical information are contained in appendix II.

2.3 THE RESULTS

The profitability of poplar growing with the expected yield (350 cubic feet) and 1969 prices is noted in table 2. The internal rates of return were 9 per cent for real costs and 12·5 per cent to 13 per cent for cash costs. When cash costs only were considered the annuity was $48 per acre as against $31 per acre for real costs. The overdraft which was building up over the development period of 17 years was paid off after 4 years of fellings; the payback period for cash costs was therefore 21 years. The payback period for real costs was not calculated because of the inclusion of opportunity costs in this category.

TABLE 2

Profitability at Current Prices and Expected Yields

Criterion	Units	With cash costs	With real costs
Annuity	$ per acre ..	48	31
I.R.R.	Per cent ..	12·5 to 13	9
Payback period	Years	21	..

The sensitivity of profits to a range of yields and prices was examined in terms of real costs (tables 3 and 4). The lowest internal rate of return was 7 per cent and the highest 10 per cent. In terms of annuities, the variation was from $11 per acre to $40 per acre. With current prices and the lowest yield that was envisaged, the annuity was still $21 per acre. For any given price the annuities rise about $18 above their respective base levels as the yield increases by 100 cubic feet of average annual increment. Each extra cubic foot of yield is therefore worth an extra 18 cents profit per acre above this level.

TABLE 3

Profitability of Poplars: Annuity ($ per acre at 6 per cent) with Real Costs

Price structure	Yields as M.A.I. in cubic feet*				
	300	325	350	375	400
Current	21	26	31	36	40
"Development" ..	13	17	21	25	29
Cautious	11	15	19	23	27

* M.A.I.—Mean annual timber increment. This is an annual growth concept analogous to average product.

TABLE 4

*Profitability of Poplars: Internal Rates of Return (per cent) with Real Costs**

Price structure	Yields as M.A.I. in cubic feet				
	300	325	350	375	400
Current	8·5	8·5	9·0	9·5	10·0
"Development" ..	7·5	8·0	8·5	8·5	9·0
Cautious	7·0	7·5	8·0	8·5	8·5

* Rounded to the nearest one-half per cent.

The comparisons with existing farming can be made from the tables. The results for real costs are used since the farm survey data includes a managerial allowance and a 6 per cent opportunity cost of capital. Poplar growing was more profitable than the average farm ($4), for all yield levels and all price levels, that is even at the cautious prices which are 20 per cent lower than current prices. Poplar growing was more profitable than 85 per cent of the existing farms ($16) for all yield levels at current prices, and at all price levels if yields did not fall below expected levels.

These comparisons apply to the 27,000 acres of prime poplar land. They can be summarized as follows. Unless relative prices move so that plywood prices fall more than 20 per cent with respect to the agricultural prices, poplar growing is at least twice as profitable as the average whole farm. Unless yields fall below the expected level, or prices below the current level, poplar growing is more profitable than 85 per cent of existing farms.

The results for plantations on the other floodplains were obtained by adjusting the transport costs. The annuity for cash costs, expected yields and current prices for the Clarence was $48 per acre, for the MacLeay $46, for the Richmond $50, and for the Tweed $51. The values for real costs were as follows: MacLeay $29, Clarence $31, Richmond $33, and Tweed $34. These differences are small in absolute terms and far smaller than the differences due to changes in yield and price structure at a given site.

3 THE INTEGRATION OF POPLAR GROWING AND FARM ACTIVITIES

3.1 THE CASE FOR INTEGRATION

The previous analysis compared the profitability of poplar growing with that of existing whole farms and, as is implicit in this type of benefit/cost analysis, assumed that these were two mutually exclusive alternatives. It is now necessary to consider the two as complementary activities which should be integrated into farm land use.

There are two arguments in favour of integration. First, the timing and quantity of the labour requirements for poplars may complement rather than compete with other farm activities—August plantings may coincide with the dry period for a spring calving herd. Second, there is considerable grazing potential under the poplar trees for some of the 18-year period. Grazing and timber production can therefore be carried out simultaneously. These two considerations suggest there may be considerable scope for integration. They could ease the problems of conversion to poplars by preventing large drops in incomes during the conversion period.

The analysis is therefore continued to answer the following questions. Is it profitable to integrate poplars with other farm activities? If so, how do optimal land use patterns vary with prices, farm size, and labour availabilities. A simple linear programme was developed which used the results and model from the previous analysis to give the gross margins and resource requirements for poplars. The poplar activity was a sustained yield model treated as a normal land development activity with annuities (discounted at 6 per cent) used for the gross margin. This follows Coutu and Ellertsen [5] who used annuities to calculate gross margins for forestry activities.

3.2 FARM ACTIVITIES AND FARM RESOURCES

The average farm size in Schaefer's survey [8] of floodplain farms was 125 acres, all of which was rich alluvial soil highly suited to pasture, poplars, and to some crops. On average one-and-a-half man units of labour, or 263 hours per month, were available throughout the year.

The dairy activity which was selected was well above average with a gross margin of $104 per animal (appendix III). The basic poplar gross margin was $58: derived from the annuity of $48 at cash costs (table 2) adjusted by $10 for rates and for depreciation on machinery already owned. As discussed in appendix III, two restraints were imposed—the maximum area for potatoes was set at 40 acres and the minimum number of cows was set at 40.

3.3 SOME INITIAL LAND USE PATTERNS

Some initial solutions for the 125 acre farm with one-and-one-half man units of labour are shown in table 5. When poplars are included without crops they occupy 52 acres or 42 per cent of the land: with crops they occupy 70 acres or 63 per cent. The area under natural pasture decreases when poplars are introduced and again when crops are considered. Potatoes enter the pattern up to the constraint of 40 acres.

TABLE 5

Some Initial Land Use Patterns

Activity	Units	Without poplars		With poplars	
		With crops	Without crops	With crops	Without crops
Dairy	Numbers	64	72	40	68
Vealers	Numbers	0	36	53	34
Pigs	Sows	0	0	0	0
Sell Bobby Calves	Numbers	12	0	8	13
Sell Heifers	Numbers	0	14	0	0
Rear Replacements	Numbers	16	18	10	17
Buy Replacements	Numbers	0	0	0	0
Skim buy	Gallons	0	0	0	0
Feed buy Spring	lb D.O.M.	0	0	0	0
Feed buy Summer	lb D.O.M.	0	0	0	0
Feed buy Autumn	lb D.O.M.	0	0	0	0
Feed buy Winter	lb D.O.M.	0	0	0	2,000
Pasture Improved	Acres	0	0	0	0
Pasture Natural	Acres	85	125	15	73
Poplars	Acres	0	0	70	52
Maize/graze	Acres	0	0	0	0
Maize/potatoes	Acres	0	0	15	0
Oats/graze	Acres	0	0	0	0
Oats/potatoes	Acres	40	0	25	0
Total Gross Margin	$	14,000	9,300	17,000	11,300

D.O.M.—Digestible organic matter.

There is a range of gross margins from $9,300 to $17,000. Poplars are included both with and without crops, and increase incomes by at least 20 per cent.

3.4 SENSITIVITY OF OPTIMAL PLANS TO CHANGES IN POPLAR GROSS MARGIN

At a gross margin of $118 per acre, which is double the base estimate, poplars occupy 81 of the 125 acres (65 per cent). Farm plans are stable within the range of $26 to $70, which includes the base estimate of $58. If the poplar gross margin falls below $17 per acre there is no place for poplars in the land use pattern (table 6).

TABLE 6

Sensitivity of Optimal Plans to Changes in Poplar Gross Margin (crops excluded)

Activity	Range in gross margin ($ per acre)					
	118 to 97	97 to 70	70 to 26	26 to 18	18 to 17	Below 17
Dairy	40	46	68	68	72	72
Vealers	56	69	34	34	36	36
Pigs	0	0	0	0	0	0
Sell bobby calves ..	8	9	13	13	0	0
Sell heifers	0	0	0	0	14	14
Rear Replacements ..	10	11	17	17	18	18
Buy Replacements ..	0	0	0	0	0	0
Skim buy	0	0	0	0	0	0
Feed buy Spring* ..	0	0	0	0	0	0
Feed buy Summer* ..	0	0	0	0	0	0
Feed buy Autumn* ..	0	0	0	0	0	0
Feed buy Winter* ..	16	19	2	0	0	0
Pasture natural	44	55	73	78	121	125
Pasture improved ..	0	0	0	0	0	0
Poplars	81	70	52	47	4	0

* Units in '000 lb digestible organic matter; otherwise as in table 5.

A fall in poplar gross margin to $17 represents a fall in price of 40 cents or 60 per cent (table 7) from their present level. A gross margin of $17 is equivalent to a discount rate of 10·5 per cent with the base price and yield (table 7). Even if the yield drops to 160 cubic feet per acre, with a gross margin of $20, poplars occupy 47 of the 125 acres. Because of the stability of optimal plans about the base gross margin and the low gross margin at which the poplar activity enters the plans, there must be a considerable drop in timber prices or yields before the optimal acreage changes from 52 acres and, even more so, before the activity leaves the plans.

TABLE 7

*Relationships Between Poplar Gross Margins, Timber Yields and Prices and the Discount Rate**

Gross Margin	Yield to give G.M. with base discount rate and price	Price to give G.M. with base discount rate and yield	Discount rate to give G.M. with base price and yield
$ per acre	cubic feet M.A.I.	cents per cubic foot	Per cent
100	..	110	3·5
80	460	90	4·5
60	360	70	5·5
58	350	67	6.0
40	260	50	7.0
20	160	30	9·5
17	140	25	10·5

* The base discount rate is 6 per cent, the base price is 67 cents, and the base yield is 350 cubic feet M.A.I.

3.5 PARAMETRIC ANALYSIS

The parameters of farm size, labour supply and dairy gross margin were systematically varied to analyse the stability of farm plans and the effect of such changes on the land use pattern. The range of farm sizes was from 150 to 100 acres: the range of labour forces was from one to three men. The main results of this analysis are now summarized.

(a) Even if the dairy gross margin (without crops) rises to $126 per acre, approximately twice the current average, poplars occupy 52 acres of the 125. Farm plans are stable between values of $94 and $62 and include 70 acres of poplars.

(b) For a given labour force, poplars tend to occupy larger areas on larger farms, both on crop and non-crop farms.

(c) For a given farm size, increases in the labour force are accompanied by increases in the area of poplars while the labour force is less than two. With more men there is a decrease in the area of poplars with and without crops.

4 PROBLEMS OF CONVERSION

The problems of converting to poplars derive mainly from the 17-year conversion period. Difficulties which arise from farmers attitudes have been discussed elsewhere [10]. Difficulties due to possible reductions in income are now considered.

The conversion period could begin, on an optimally organized farm without poplars or crops, with an annual income of $9,300 (table 5) which would reduce as land was planted. To analyse the nature of this reduction a series of solution plans was determined with a progressive reduction of land and labour available for non-poplar activities. Incomes dropped from $9,300 in year 0 to $8,400 in year 1, and to $8,300 for years 6 to 17. This pattern is, of course, dependent on the activities which were included in the matrix. But it does appear that with the inclusion of other activities, particularly other vealer activities, and where appropriate, agistment, this drop in income can be minimized. In this example, the maximum drop in income is only 10.7 per cent even though 52 acres were introduced into a 125-acre farm.

If farmers were to finance the activity from their own resources, a time preference rate greater than 10·5 per cent would reduce the gross margin to less than $17 and *ceteris paribus* remove poplars from the optimal plan. It is likely that farmers' rates of time preference are indeed greater than 10·5 per cent so that for poplars to be included at all outside funds must be available at rates less than 10·5 per cent. The Farm Woodlot loan scheme is such a fund and has been discussed by Gardner [6], and Beale [1]. Intercropping during the development period can materially ease the problems of conversion. In Europe wheat, maize, potatoes, beets, and oats are commonly grown between the trees for the first 2 or 3 years of the development period. The profitability of inter-cropping with maize, potatoes, and oats was presented by Schaefer *et al* [9]. The profits from these activities, even with conservative estimates, compensate for all cash costs of poplar establishment. Together with the cattle in later years this system of multiple-use management could, at a conservative estimate, maintain farm gross margins through the conversion period. Beef cattle activities are combined with poplars at Grafton, and there is an example of inter-cropping with poplars on the MacLeay.

5 CONCLUSIONS

The current results indicate that there is a very wide range of timber prices, yield conditions and farm structures within which poplars should be included as a farm activity. If the price of poplar timber does not fall by more than 60 per cent relative to other prices, and if plantations can be financed at less than 10·5 per cent (compound), then poplar growing can profitably be integrated with other farm activities. These limits may eventually prove rather wide, and it does appear that poplar growing offers considerable opportunities for many farmers on the north coast. But, even so, attitudes to risk and uncertainty, and time preference may well prevent the adoption of poplars as a farm activity.

REFERENCES

[1] Beale, J. G., *The Farm Woodlot Scheme* (New South Wales Department of Conservation, Forestry Commission: Miscellaneous Leaflet, 1968).

[2] Bird, J. G., "The Dairy Industry on the Far North Coast of New South Wales", *Review of Marketing and Agricultural Economics*, Vol. 30, No. 1 (March, 1962), pp. 1–60.

[3] Bird, J. G., *Alternatives in Dairy Industry Adjustment in the Far North Coast Area of New South Wales* (N.S.W. Department of Agriculture: Miscellaneous Bulletin No. 6, 1968).

[4] Black, R. M., *Poplar Growing in New South Wales* (N.S.W. Department of Conservation, Forestry Commission, 1967).

[5] Coutu, A. J. and B. W. Ellertsen, *Farm Forestry Planning Through Linear Programming* (Tennessee Valley Authority, Report No. 236–60, 1960).

[6] Gardner, M. J., "The Availability of Finance for Tree Farming", (Paper presented to Seminar on Private Tree Farming, Lismore, August, 1969).

[7] Jacobs, M. R., "Forecasts for the Future", *Australian Timber Journal*, Vol. 32, No. 4 (May, 1956), pp. 35–45.

[8] Schaefer, N. T., *Commercial Potential of Poplars on the North Coast of New South Wales* (University of New England: Research Series in Regional Development, No. 3, 1969).

[9] Schaefer, N. T., J. A. Sinden, and E. R. Woolmington, "Agricultural Adjustment and Poplar Growing Potential on the North Coast of New South Wales" (Paper presented to ANZAAS, Adelaide, 1969).

[10] Sinden, J. A. and N. T. Schaefer, *Farmer Attitudes to Farm Forestry on the North Coast of N.S.W.* (University of New England Research Series in Regional Development No. 4, 1969).

APPENDIX I

AN ESTIMATE OF THE POTENTIAL POPLAR AREA (ACRES) ON FOUR NORTHERN RIVERS

River System	Railhead	Total flood plain area[1]	Suitable for optimum growth	90 per cent suitable[10]
Tweed	Murwillumbah ..	16,000[2]	6,100[8]	5,500
Richmond	Lismore ..	68,000[2]	2,700[9]	2,400
Clarence[3]	Grafton	126,000	5,000[7]	4,500
MacLeay[4]	Kempsey ..	42,000[5]	16,000[6]	14,500
Total	.. .. ..	252,000	29,800	26,800

[1] Excluding all secondary valleys—for example above Kempsey on the MacLeay and above the Lismore and Woodburn flats for the Richmond.

[2] Derived from the map accompanying Bird [2].

[3] Data derived from Schaefer [8].

[4] From a Commonwealth Scientific and Industrial Research Organization soil map.

[5] Area to bottom of levees only, that is the soil associations of Glenrock, Euroka-Cooroobong, Kempsey-Cooroobong.

[6] The latter two soil associations only (38 per cent of total area).

[7] The available area within 400 yards of the river above Lower Southgate at which point local experience notes that the ground water is often saline.

[8] Thirty-eight per cent of 68,000 on the assumption, based on local advice, that soil conditions are broadly similar to those on the MacLeay.

[9] Four per cent of 68,000 on the assumption that salinity and clay conditions are similar to the Clarence.

[10] Allows 10 per cent for roads, etc.

APPENDIX II

COST AND YIELD DATA FOR POPLARS

Machinery Costs

	$
Rotary Hoe	920
Pruning Equipment	550
Tractor	420
	1,890

It was assumed that all machinery was purchased at the beginning of year 1, replaced every 20 years, that a poplar activity used 15 per cent of the costs of the tractor, and that a post hole auger was already available.

Establishment Costs (Year 1)

	$
Fencing	5
Ploughing (twice)	10
Cultivating	5
Plants and Planting	100
Pruning	10
	130

Total costs excluding labour were taken as $80.

Land costs

The market value of the land with fences, water and improvements but excluding stock was taken at $350 per acre.

Annual costs

An annual cost of $6 per acre was taken to cover rates and costs of protection against vermin, pathogens and other pests.

Tending costs

Year	Operations	$ per acre	
		Total cost	Cost excluding labour
2	Pruning, cultivation	10	5
3	Pruning	7	3
4	Pruning	7	3
5	Pruning	9	3
6	Pruning (final to 35 feet) ..	10	4

Source: These costs apply to the establishment of poplar plantations on alluvial flats. They are based on local experience and prospects as well as on Schaefer [8].

Yields

For an eighteen-year rotation, growth rates on predictions by Federal Match Forests Pty Ltd at Grafton are 420 cubic feet mean annual increment for *Populus deltoides var angulata* and 465 for the newer *texas provenance*. In the analysis, expected yields were based on a more conservative value of 350 cubic feet. A thinning of 930 cubic feet was taken at age eight and the final yield 5,370 cubic feet was felled at age eighteen. The effect of changes in yields on profitability was examined by using a range from 300 to 400 cubic feet mean annual increment. From local and South African experience, it was assumed that 90 per cent of the final crop, or 76 per cent of total volume production of 350 cubic feet M.A.I., would be suitable for the plywood market.

APPENDIX III

DETAILS OF THE ACTIVITIES

(a) *Dairying*

A butterfat level of 330 pounds per year, a lactation period of 8 months, and spring calving were assumed. In addition to liquid milk sales the gross margin included the sale of cull cows after four lactations. No skim supplies were available for other activities. Calves for rearing as replacements (activity 6); selling as bobby calves (activity 4) or as heifers (activity 5) were available at the rate of 0·44 per herd unit. Herd composition was 60 per cent milkers, 13 percent heifers and the remainder calves, yearlings and bulls. Feed requirements were expressed in pounds of digestible organic matter per season per herd unit and were taken from the annual reports of the Wollongbar Research Station, Department of Agriculture of New South Wales. Labour requirements are varied through the year. A restraint establishing the minimum herd size at 40 animals was included: it was felt that the farmer's experience and income requirements through a development period justified the restraint.

(b) *Vealers*

Autumn calving was assumed together with production of three vealers before the need to cull. The vealer gross margin includes the purchase of vealer mothers for $60, retention for 3 years and sale for $48. The vealer itself sells for $60 and veterinary and other variable costs amount to $16 to give a gross margin of $40 per vealer. Feed requirements were expressed in terms of a cow and calf. Labour requirements are varied through the year and were, in a conservative manner, perhaps a little high.

(c) *Pigs*

There were no pig activities on the survey farms so that data from Bird [3] were adopted. One sow with two litters per year requires approximately 6,000 pounds of digestible organic matter or gallons of skim milk. When crops are included a maize/pig-feed transfer activity (25) permits selection of either feed. Pigs are sold as porkers at $100.

(d) *The use of calves*

Activities 4 and 5 and 6 allow calves to be sold as bobby calves, heifers or reared as replacements whichever choice is appropriate to the plan. The sale of bobby calves at 2 weeks for $11 total revenue yields a gross margin of $9. A variable cost of $7 is deducted from a total revenue of $45 for heifer sales to give the gross margin of $38. The cost of 200 gallons of skim milk is included in the cost of rearing replacements.

Activity 7 permits the buying of replacements capable of 330 pounds of butterfat.

(e) *Feed purchases*

The purchase of skim milk (activity 8) for the pigs at 3 cents per gallon is self explanatory. Activities 9, 10, 11, and 12 permit the purchase of lucerne to supplement food supplies, with the more expensive supplies in winter and autumn.

(f) *Crops*

Since it is technically possible to grow maize in rotation with potatoes, and oats in rotation with potatoes, activities 16, 17, and 18 were included to allow for rotation combinations and activities 19 and 20 to allow for maize with pasture for the rest of the year and oats with pasture for the rest of the year.

Maize yields were assumed to be 80 bushels per acre with planting in November and stripping in April. Through storage it can be fed at any time of the year (transfer activities 21, 22, 23, and 24). At 58 pounds per bushel and 95 per cent conversion to digestible organic matter, maize can supply 4,400 pounds of feed.

Oats (activity 20) are assumed to supply grazing feed of 1,860 units in winter and 840 in autumn. They are sown in March. The gross margin of $23 allows for the seed and maintenance of the pasture which becomes available in spring and summer after the oats are grazed off.

Potatoes are grown by a small number of farmers along the rivers and the gross margin of $189 is derived from $4 per bag and 96 bags per acre, contract lifting in November ($64 per acre), freight ($38), fertilizer ($55), and seed ($38). The price of $4 is conservative since November is a seasonal peak for potatoe prices. Due to the wide annual variation in potato prices, and the technological superiority of sites elsewhere, a maximum limit of 40 acres was placed on the area of potatoes.

(g) *Pasture activities*

The native kikuyu pasture supplies a considerable quantity of feed at no resource cost (activity 14). The improved pasture activity includes top-dressing with sulphate of ammonia. Fertilizer was applied at 2 cwt per acre for six applications: the gross margin for the improved pasture includes freight, spreading and fertilizer costs.

(h) *Poplar growing*

Trees are planted in August after ploughings in the previous September and May and cultivation in January. Pruning in each of the first 6 years is in August, further cultivations are in years 2 and 3.

The feed supplies are from the natural kikuyu pasture under the trees and peak in summer with a considerably reduced supply in winter. The level of supplies is based on known carrying capacities. One beef unit (cow plus calf) can be carried on 3 acres. Only plantations of 3 to 10 years can achieve this (7/18 of the rotation). Thus in spring feed supplies per acre of an 18-acre unit are ($7/18 \times 578 \times 1/3$) or 75 feed units.

The gross margin is derived from profitability with cash costs but excludes rates and the cost of tractor and cultivation equipment. It is therefore analogous to gross margin for shorter term pasture improvement programmes. Labour requirements are calculated on the basis of the sustained yield model and so represent requirements from year 18 onwards. They are higher than in any of the previous 17 years.

APPENDIX III

Table 1, Part I

The Basic Linear Programming Model

Activity	B	1	2	3	4	5	6	7
		Dairy	Vealer	Pig	Bobby sell	Heifer sell	Rear	Buy
							Replacements	
Gross Margin	..	104	40	216	9·0	38·0	—10·8	—90·0
1 Land	..	..	..	..	..	..	..	..
2 Heifer supply	..	—0·44	..	..	1·0	1·0	1·0	..
3 Springer supply	..	0·25	..	..	..	..	—1·0	—1·0
Labour—								
4 July	..	2·0	1·0	5·0	..	0·75	1·0	..
5 August	..	2·0	0·5	5·0	..	0·75	1·0	..
6 September	..	3·0	0·5	5·0	..	0·75	1·0	..
7 October	..	3·0	0·5	5·0	..	0·75	1·0	..
8 November	..	3·0	0·5	5·0	..	0·75	1·0	..
9 December	..	2·5	0·5	5·0	..	0·75	1·0	..
10 January	..	2·5	0·5	5·0	..	0·75	1·0	..
11 February	..	2·5	0·5	5·0	..	0·75	1·0	..
12 March	..	2·5	1·5	5·0	..	0·75	1·0	..
13 April	..	2·5	1·5	5·0	..	0·75	1·0	..
14 May	..	2·5	1·5	5·0	..	0·75	1·0	..
15 June	..	2·0	1·5	5·0	..	0·75	1·0	..
Feed Pool—								
16 Spring	..	566·0	578·0	..	..	1,410·0	..	..
17 Summer	..	508·0	621·0	..	..	1,410·0	..	..
18 Autumn	..	462·0	673·0	..	..	1,410·0	..	..
19 Winter	..	380·0	468·0	..	..	1,410·0	..	..
20 Maize Pool	..	..	..	..	..	..	..	..
21 Pig Feed	..	..	..	6,000·0	..	..	..	..
22 Potato Constraint ..	40	..	..	..	..	..	..	..
23 Rotation Pool	0	..	..	..	..	..	..	..
24 Cow Constraint ..	40	1·0	..	..	..	..	..	..

APPENDIX III

Table 1, Part II

	8	9	10	11	12	13	14	15
	Buy skim	Buy feed				Poplar	Pasture native	Pasture improved
		Spring	Summer	Autumn	Winter			
G.M.	—0·30	—1·9	—1·8	—2·2	—2·2	58·0	—0·0	—69.0
1	. .	. .	. .	. .	. .	1·0	1·0	1·0
2	. .	. .	. .	. .	. .	. .	. .	. .
3	. .	. .	. .	. .	. .	. .	. .	. .
4	. .	. .	. .	. .	. .	. .	. .	. .
5	. .	. .	. .	. .	. .	1·8	. .	1·5
6	. .	. .	. .	. .	. .	0·5	. .	. .
7	. .	. .	. .	. .	. .	. .	. .	. .
8	. .	. .	. .	. .	. .	. .	. .	1·5
9	. .	. .	. .	. .	. .	. .	. .	. .
10	. .	. .	. .	. .	. .	0·9	. .	. .
11	. .	. .	. .	. .	. .	. .	. .	1·5
12	. .	. .	. .	. .	. .	. .	. .	. .
13	. .	. .	. .	. .	. .	. .	. .	. .
14	. .	. .	. .	. .	. .	0·5	. .	1·5
15	. .	. .	. .	. .	. .	. .	. .	. .
16	. .	—100	. .	. .	. .	—75	—1,290	—3,130
17	. .	. .	—100	. .	. .	—81	—1,510	—3,920
18	. .	. .	. .	—100	. .	—66	—1,140	—1,970
19	. .	. .	. .	. .	—100	—30	— 520	—1,190
20	. .	. .	. .	. .	. .	. .	. .	. .
21	—10·0	. .	. .	. .	. .	. .	. .	. .
22	. .	. .	. .	. .	. .	. .	. .	. .
23	. .	. .	. .	. .	. .	. .	. .	. .
24	. .	. .		. .	. .	. .	. .	. .

APPENDIX III

Table 1, Part III

	16	17	18	19	20	21	22	23	24	25
	Maize	Pot's	Oats	Maize/ Graze	Oats/ Graze	Transfer Activities				
						Sp.	Su.	Au.	Win.	M/PF
G.M.	—29	189.0	—18.0	—35.0	—23.0	...	...	...	. .	. .
1	0.5	0.5	0.5	1.0	!.0	...	...	...	. .	. .
2	...	...	...	...	. .	...	...	...	. .	. .
3	...	. .	...	...	. .	...	...	...	. .	. .
4	...	3.0	...	...	. .	...	...	. .	. .	. .
5	...	0.5	...	...	. .	...	...	. .	. .	. .
6	...	0.5	...	...	. .	...	. .	...	. .	. .
7	2.0	...	...	2.0	. .	...	...	. .	. .	. .
8	3.0	...	...	3.0	. .	...	...	...	...	. .
9	...	...	...	...	. .	...	...	...	. .	. .
10	...	...	...	...	. .	...	...	. .	...	. .
11	...	...	...	...	. .	. .	...	...	. .	. .
12	...	...	2.0	...	2.0	. .	...	...	. .	. .
13	2.0	...	...	2.0	. .	. .	...	. .	. .	. .
14	...	1.0	...	. .	. .	. .	...	. .	. .	. .
15	...	1.0	...	. .	. .	. .	...	. .	. .	. .
16	. .	...	...	—400	—1000	—1	...	. .	. .	. .
17	. .	...	...	...	—1100	. .	—1	...	. .	. .
18	...	...	—840	—350	— 840	. .	...	—1	. .	. .
19	...	...	—1860	—400	—1860	. .	...	...	—1	. .
20	—44,000	...	...	—4,400	. .	1	1	1	1	1
21	...	...	...	. .	. .	. .	...	...	...	—1
22	...	1.0	...	. .	. .	. .	...	...	. .	. .
23	—1.0	1.0	—1.0	. .	. .	. .	...	...	. .	. .
24	...	...	...	. .	. .		...	. .	. .	. .